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A Competence-Based Course Authoring Concept for Learning Platforms with Legacy Assignment Tools

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***Abstract*— This paper is concerned with several of the most important aspects of *Competence-Based Learning (CBL)*: course authoring, assignments, and categorization of learning content. The latter is part of the so-called *Bologna Process (BP)* and can effectively be supported by integrating knowledge resources like, e.g., standardized skill and competence taxonomies into the target implementation approach, aiming at making effective use of an open integration architecture while fostering the interoperability of hybrid knowledge-based e-learning solutions. Modern scenarios ask for interoperable software solutions to seamlessly integrate existing e-learning infrastructures and legacy tools with innovative technologies while being cognitively efficient to handle. In this way, prospective users are enabled to use them without learning overheads. At the same time, methods of *Learning Design (LD)* in combination with CBL are getting more and more important for production and maintenance of easy to facilitate solutions. We present our approach of developing a competence-based course-authoring and assignment support software. It is bridging the gaps between contemporary *Learning Management Systems (LMS)* and established legacy learning infrastructures by embedding existing resources via *Learning Tools Interoperability (LTI)*. Furthermore, the underlying conceptual architecture for this integration approach will be explained. In addition, a competence management structure based on knowledge technologies supporting standardized skill and competence taxonomies will be introduced. The overall goal is to develop a software solution which will not only flawlessly merge into a legacy platform and several other learning environments, but also remain intuitively usable. As a proof of concept, the so-called *platform independent conceptual architecture model* will be validated by a concrete use case scenario.**

Keywords*— Competence Based Learning; HEI; LMS; LCMS; e-learning tools; interoperability; course authoring tools; Moodle; LTI; Moodle plugins; hybrid tool solutions; assignments; legacy tools; platform bridges; taxonomy; IMS Learning Design.

I. Introduction, Motivation and Approach

Learning Management Systems (LMS) as well as ***Learning Content Management Systems (LCMS)*** nowadays are essential elements of ***Higher-Education Institutions' (HEIs)*** educational infrastructures. Driven by this trend, innovative learning scenarios emerge while triggering the evolution of this kind of e-learning software systems and corresponding overall academic teaching and training infrastructures. At the same time, innovative features in such educational software systems can (and should) inspire ambitious ideas for further developing teaching- and learning concepts or organization-corresponding software-application scenarios so that the development of e-learning-software constantly progresses. In this way the needs for cognitive efficient and at the same time technically interoperable and therefore transparently usable tools to support effective learning content creation and consumption approaches of their users are growing.

Although the rapid improvement of these technologies is appreciated, it is coming with a price-tag: users with an intuitive approach to modern technologies might perceive the learning processes for the usage of a new software as an obstacle. For this reason, it is desirable that formerly accustomed workflows are changed as little as possible. To learn the handling of new interfaces and programs, tutors, teachers, and professors - especially when they are not working within the field of information technologies - need to invest a distinctively high amount of time to get familiar with every piece of unknown software in their scholastic infrastructure. Therefore, it is crucial to keep the learning curve as flat as possible. Even if the recent developments might help to work more efficiently and effectively, in the end there are still too many hours to invest in learning new skills. These efforts are lost for the educational process itself.

Modern learning scenarios do not only require teachers and faculty to get familiar with but also students need to learn about available technologies and services. This means, that teachers are constantly faced with students' questions about new platforms, features, and add-ons. In this way, a certain amount of their teaching time goes into explaining the bits and pieces of most-recent learning tool developments to their students. Especially in adult education and if students do not belong to the generation of so-called *digital natives,* they often fail to understand the use of new platforms quickly enough to allow for a satisfactory learning experience.

While new tools for the development and evolution of e-learning infrastructures and learning environments are needed, students and teachers should not only be embraced by the change but feel inclined to try out new features without being confronted with having to study bulky manuals for every single feature of increasingly growing platforms or software-packages, such as, e.g., the LMS and LCMS ***Moodle*** [1].

Depending on the organization of HEIs, teaching fellows are employed to ease the way into new technologies for students and to help in the process of studying as such. However, as teaching fellows eventually are recruited from the experienced student-corpus, they typically stay for a limited amount of time in this job position resulting again in a towering amount of paid working time, which is lost when they leave from their position. The problem of such high fluctuation of costly trained and specialized workforce emerges frequently and adds to the work load of the permanent staff.

As a consequence, for example, an easy to learn and use ***Course Authoring Tool (CAT)*** for producing content for LMSs would not only save time and trouble for the teachers but would also help HEIs to safe monetary resources in training teaching assistants.

Along with the BP [2], lectures are provided with academic credit points according to the ***European Credit Transfer System (ECTS)*** [3]. Furthermore, the skills conveyed by a lecture have to be stated and categorized in a determined way by assigning so-called ***Competences***. This scheme is a binding standard for all accredited courses by European universities and colleges participating in the BP, in order to enable students to integrate a greater flexibility into their curricula. Therefore, contemporary learning environments have to offer the best possible support for such requirements, meaning that online courses and learning content have to be tagged as knowledge resources with competence information.

For more than 40 years the ***University of Hagen*** (German Fern-Universität Hagen, in short ***FernUni*** or ***FUH)*** with today more than 75.000 students the largest distance-education university of the German-speaking countries is a stately acknowledged, accredited, and publicly funded HEI providing education at an academic level via distance learning technologies. Besides the core software systems like an in-house developed campus management system and an enhanced FernUni-specific Moodle-version with about 70.000 users and single courses exceeding 10.000 participants, numerous additional learning tools are provided. This includes a video portal, a wiki, and several communication tools as well as the legacy assignment software ***WebAssign (WA)*** [4] [5] which originally has been developed at FernUni's department of Mathematics and Computer Science at the Chair of Software Engineering. In addition to facilities and online resources, printed material is delivered to every student's doorstep. Professors, teaching fellows, tutors, and graders help students along their journeys towards the aimed academic degree or certification. Different assignment types have been developed to engage students in learning processes and communication. The grading of these assignments is partly managed by the virtual learning environment and partly done by graders.

II. Problem Statement, Research Questions, Objectives and Approach

This paper will outline a concept for developing an effective and at the same time powerful learning-content authoring software which provides support for competences in the meaning of the Bologna Process while integrating different technologies transparently so that it will be comfortable and cognitively efficient to handle for non-computer scientists.

As indicated by its name, the CAT focusses on its main tasks to offer a user-friendly way for creation and modification of learning content. These resources, for example courses containing assignments, forums and pdf files, will be provided by and consumed in different contemporary learning management systems.

Offering support for modern learning scenarios and keeping up accustomed workflows at the same time requires a software solution which includes support for an educational institution's established legacy tools. To avoid these tools being perceived as outdated appendages, they should be ideally treated as regular components of the LMS. A common way to embed external tools is using a so-called ***iframe*** [6]. Upcoming technologies like ***Learning Tools Interoperability (LTI)*** [7] [8] enhance this idea with ***Single Sign On (SSO)*** technologies like ***OAuth*** [9] [10] and enable the involved systems to exchange data like graders' feedbacks to students' exercises.

Incorporating functionality for managing machine-readable representations of competences (ideally based on an underlying knowledge technology representing standardized skills and competence taxonomies) is primarily motivated by the Bologna Process, but it also offers interesting perspectives when focusing on advanced features like platform-independent semantic tagging of courses with learning goals and preconditions for participation. Such information can be used to introduce, e.g., content-syndication functionality. As a result, suitable knowledge and learning resources can automatically be identified and recommended to users. This is considered a beneficial feature for teachers during a course creation process as well as for students, when they initiate a search for additional courses and relevant material. In order not to be limited to a local knowledge resource database, generic interfaces (restricted to certain communities) for distributed online content and knowledge repositories need to be developed, integrated, and provided.

For certification purposes, and to measure course participants' learning success in general, an automated method for evaluating their performance needs to be developed; self-assessments appear to be an appropriate way here. In addition:

self-assessments can be used for checking of students' existing skills and competences and to which degree they meet the required preconditions to enter a course or access a learning resource.

Outsourcing core functionality like course creation from learning management systems into separate authoring tools as a CAT requires a technology for transferring learning content to the LMS. In recent years several appropriate xml-based exchange formats have been developed. This includes ***IMS Learning Design (IMS LD)*** [11]-[13]. Therefore, it seems reasonable to decide upon a solution based on available standards instead of re-inventing the wheel. As none of the existing exchange formats supports the categorization of learning content in a BP-conform way, our objective requires some extensions in order to incorporate a new framing software connecting the different educational platforms.

A. Learning Environment at FernUni in Hagen

The approach outlined above is optimized for the particular needs of educational institutions like FernUni which process their lectures by using virtual learning environments. Consequently, distance education at FernUni will be taken as a first use case scenario. Leaving the platform-independent level of development, the next step is to analyze FernUni's tool landscape and technical requirements as well as the needs of scholars and students.

Since Moodle [1] is widely known and used as an LMS and LCMS, FernUni is already using it since a while in several areas of its educational environment. Other than the proprietary competitor ***Blackboard*** [14], Moodle as a so-called ***Open Source Solution (OSS)*** is the platform of choice for our experimental scenario. An alternative to the OSS standard Moodle could be *Totara* [42] [43], a Moodle spin-off optimized for continuing vocational training in enterprises, which supports competences and is available in an open-source community edition and a commercial enterprise edition. However, Totara's workflows concerning courses and competences do not really match with FernUni's requirements, so the standard OSS Moodle will remain the LMS of choice. In combination with several other tools, it is considered a powerful and at the same time open and flexible base system for our research.

Within its course model, Moodle supports many so-called ***Moodle Activities (MA)***, offering features like assignments, forums, chat rooms or wikis. All these activities are implemented as so-called ***Moodle Plugins (MP)***. They are sufficient for most requirements, but they do not offer the same comfort and variety of functionality as specialized software focusing on a single aspect of e-learning support. Therefore, it is necessary to connect external tools and platforms to Moodle to be enabled to use both: the advantages of Moodle and the best features of additional learning tools and platforms. The Moodle open-source software-development community has identified these needs and created a plugin for this purpose using LTI [7] [8].

To get an idea about the need for (and requirements towards) additional tools to be integrated with the already existing Moodle tool suite, we have interviewed teachers, staff and students at *FernUni*. These interviews have led to the conclusion that legacy tools still do play a significant role, in particular the assignment software WA. Several online-tools have been developed during the last decades at FernUni. These are individually tailored to the needs of faculty and students. Most of these initially used in-house software solutions are (at least to some degree) outdated today and quite a few even have been replaced lately. However, some of these legacy tools are still in use and moreover they are widely accepted.

Especially in the case of WA (an assignment tool supporting FernUni-specific workflows) it is not easy to find an alternative. Besides this, numerous teachers used it for decades and therefore have spent a significant effort for developing their assignment-scenarios and teaching-environments. These users would be, to say the least, dissatisfied with a mere replacement. Therefore, WA will be kept as a legacy tool, ideally embedded or transparently integrated into Moodle.

A first step to find a solution is to explore the possibilities and features of the LTI standard which according to its developers in [7] [8] specifies a way for integrating learning applications into e-learning platforms. The effort for making software like WA compatible to LTI seems to be maintainable and (regarding the benefit) justified. A requirement analysis and system integration specification for embedding WA into Moodle via LTI will be discussed later.

Course creation should be attended by a user-friendly and easy to handle authoring tool. The overall goal and initial objective of our research work is to develop an authoring tool for Moodle courses. It will make it easier for teachers to intuitively create new learning scenarios in Moodle, aiming for a genuine user-interface and supporting the *What-you-see-is-what-you-get (WYSIWYG)* paradigm. At the same time it will support the integration of additional resources into such Moodle courses based upon the LTI technology.

FernUni supports advanced training programs in addition to academic courses concerning regular study paths. More often than not, these programs run in cooperation with external institutions which (at least in several cases) have their own e-learning platforms. One of them is heading towards supporting CBL scenarios [15][16][17][18] and therefore would appreciate the integration of advanced solutions for managing, categorizing, and exchanging learning content into Moodle.

Supporting CBL affects the way to integrate external tools like WA into Moodle, because CBL specific information has to be inserted and shared.

III. STATE OF THE ART AND TECHNOLOGY

Former research projects already worked on related problems and therefore in a few cases offer partial solutions for our objectives or appropriate starting points for further development. These are:

- IMS LD [11] [12] [13];
- CBL [15] and the ***TENCompetence Personal Competence Domain Model (PCDM)*** [16];
- the 2012 ***ACM Computing Classification System (ACCS)*** [19];
- IMS LTI [7] [8];

These approaches and specifications have (at least partly) been implemented by the following software platforms:

- the ***Personal Competence Manager (PCM)*** [18] [20] [21]
- the GLOBIT ***Ecosystem Portal (EP)*** toolkit [23];
- Moodle and its ***LTI Consumer Plugin (LTICP)*** [22].

Using existing technology is not entirely sufficient to reach our goals: Therefore, this section concludes with an outline of remaining challenges which require new innovative solutions.

A. IMS Learning Design

IMS LD is an XML-based platform-independent specification to describe learning designs. It has been developed at the ***Open University of The Netherlands (OUNL).*** In February 2003 the first version was published [13]. IMS LD bundles a wide range of existing e-learning standards and allows the modeling of different learning strategies by using just a single language [11] [12].

IMS LD uses the metaphor of a stage-play - also called ***Unit of Learning (UOL)*** - to model learning designs. A UOL represents an enclosed educational part like a course, module or lesson, with pre-defined ***Learning Goals (LGs)*** and consists of one or more ***Learning Acts (LActs)***. An act for its part contains different ***Learning Activities (LAs)*** as reading texts or discussing the subject with peers.

An activity is assigned to a role, for example student, grader, tutor or professor. ***Learning Resources (LR)*** and their files represent the requisites of the stage-play. Figure 1 gives an overview of the conceptual model of IMS LD [12].

Depending on the complexity of a learning design, IMS LD can distinguish between three levels of modeling different teaching strategies. Each level extends and incorporates the previous. The first level (identified as “A”) contains core elements like people, activities and resources, aiming for modeling time controlled learning designs. The second level (identified as “B”) extends the first level through conditions and rules. In this way, complex branching and workflows are made possible. The third level (identified as “C”) adds notifications to the learning design similar to an RSS-feed to inform tutors when assignments are handed in by students.

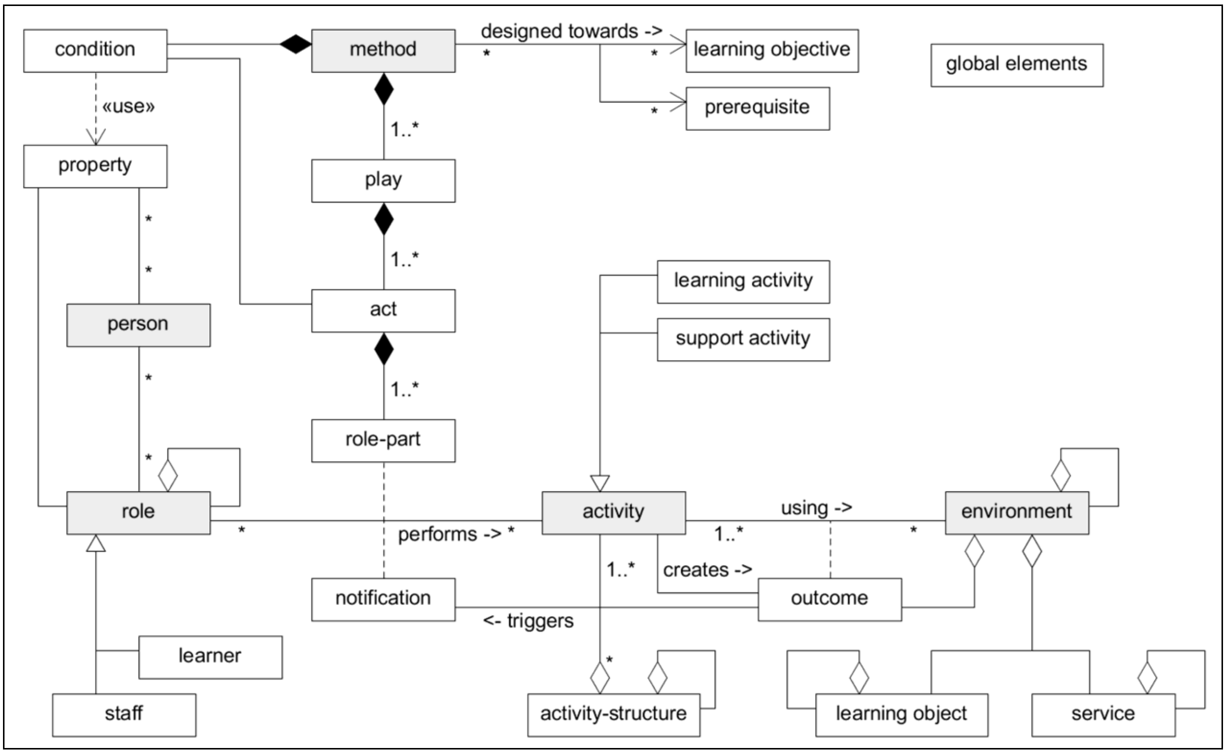

Figure 1: Conceptual model of the IMS LD [12]

B. Competence Based Learning

According to the BP, skills conveyed by lectures or study resources have to be stated and categorized by means of so-called competences. As this is a binding standard for all accredited (and therefore academically acknowledged) courses by most European universities and colleges, contemporary learning environments should offer the best possible support for this.

A lot of research on this topic has been done in the context of the ***TENCompetence*** project [15]. This approach is targeted to life-long learners, professionals, and students. Therefore, its support requires a software which not only bridges the gap between traditional learning platforms and modern solutions like Moodle, but also comes with a thorough support to enable institutions to single out different materials for the creation of new courses outside the higher-education curriculum. This applies for example to course productions targeting at accredited or certified courses in ***Continuous Professional Education (CPE)***.

Within CBL a ***Competence (C)*** is the acquired or perceived

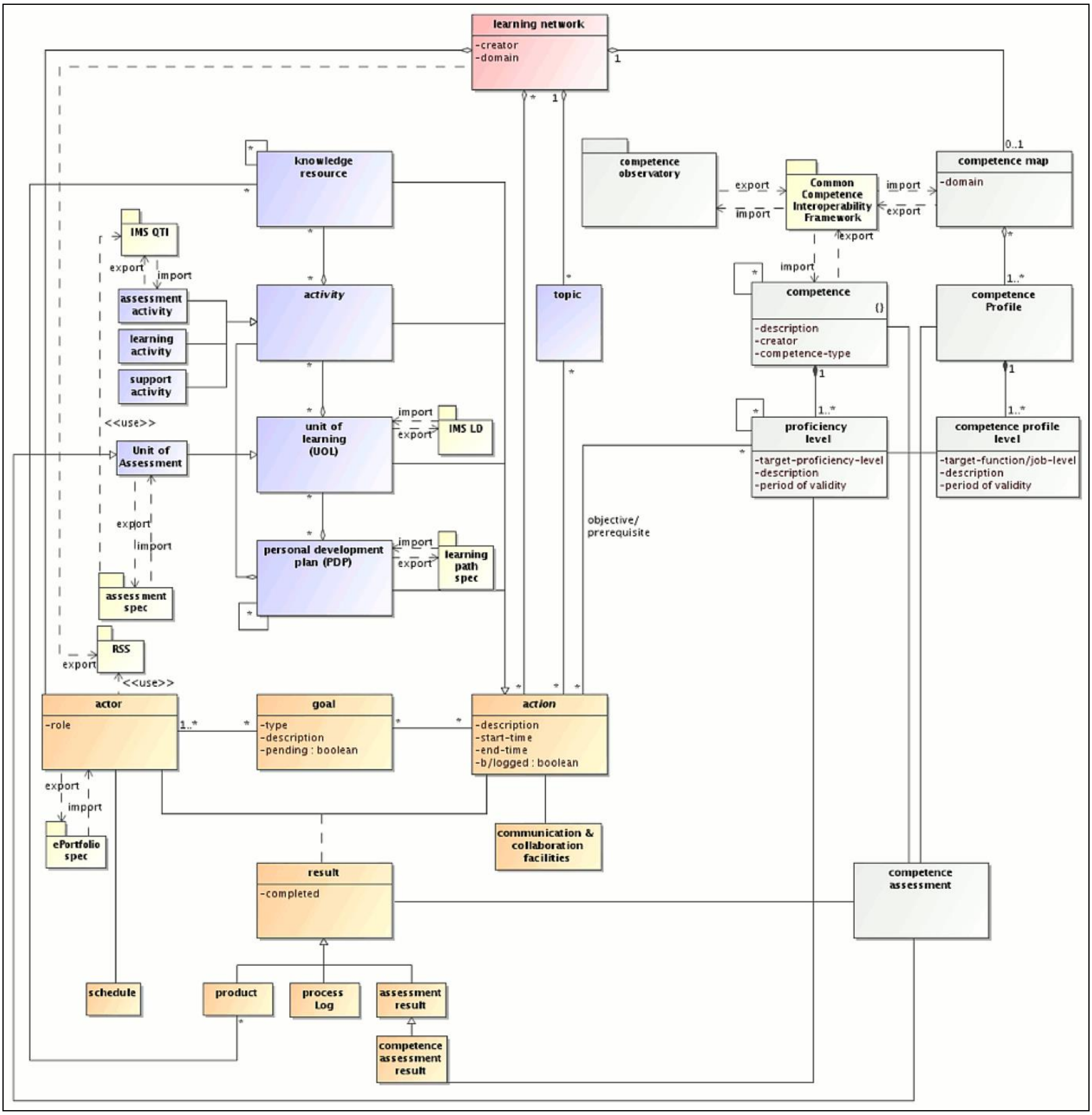

Figure 2: UML Class Diagram of the TENCompetence Domain Model [16]

skill of a person, group, or an organization to handle critical events, problems, or tasks in certain situations, for example within computer science education and training to master object-oriented programming techniques. The acquisition, perception or possession of such skills can typically be proven, documented or certified by self-assessment, informal or formal assessments with feedbacks and markings by graders, tutors and teaching fellows, or automatically by computer programs [24]. The collection of competences to handle problems in different situations is called the ***Competence Profile (CP)***. A concrete CP might be “teaching skill in theoretical art”. Furthermore, competences and CPs have their own so-called ***Proficiency Level (PL)*** [24].

The so-called PCDM has been developed within the scope of the TENCompetence project [15]. The PCDM offers (like IMS LD) the possibilities of creating models for different learning scenarios. However, it extends these with CBL information. Figure 2 displays the ***Unified Modeling Language (UML)*** [25] class diagram of the PCDM. A core element of this model is the abstract class ***Action***; actions can be represented by

- ***Learning Activities*** (e.g., quizzes or assignments);
- ***Knowledge Resources*** (e.g. pdf-files or videos);
- ***Units of Learning*** (usually courses);
- ***Competence Development Programs (CDPs)*** [17].

Actions are executed through an actor - for example a student or a tutor - to achieve certain goals like acquiring competences for a chosen profession.

During the execution of different actions, actors produce traces of their performance. These traces can have distinct characteristics: starting with simple activity logs and not ending at the state of solid learning outcomes. Traces are used to infer the competences a learner has achieved; competences are depending on a situation-related context, and they are connected to the learning network. Different levels of competences are modeled through the PL. An alternative or additional way to find out about the competences of a student is through specific ***Competence Assessments (CA)***.

Competence Profiles (CP) and competences are always combined with a ***Learning Network (LN)***. This set is called a ***Competence Map (CM)***. Single competences can exist generically for a special domain or only for a community. An observer cares for the common and formal descriptions of generic competences to make them exchangeable between different LNs. Communities pass their evaluated competences to the observer and may share descriptions of these competences with third LNs. Each community decides which CPs and competences they would like to request or submit when they make use of the observer.

An example for a competence from within computer science education could be ‘relational database systems, pl2’. Analogue to competences CPs are graded into ***Competence Profile Levels (CPL);*** for example the CP ‘software developer in c++, cpl2’ could contain the competences ‘relational database system, pl2’, ‘programming in c++, pl3’, ‘concepts of oop, pl2’ and ‘software engineering, pl1’.

C. The 2012 ACM Computing Classification System (ACCS)

The CSS is a de-facto standard used in semantic web applications and is available at no extra cost for educational and research purposes. The first system was published 1964 from the ACM, the last one 2012. CSS represents a poly-hierarchical taxonomy with over 2000 terms and is available in the ***Simple Knowledge Organization System*** *(SKOS)* [27] format - Figure 3 shows the 13 main categories of the ACSS.

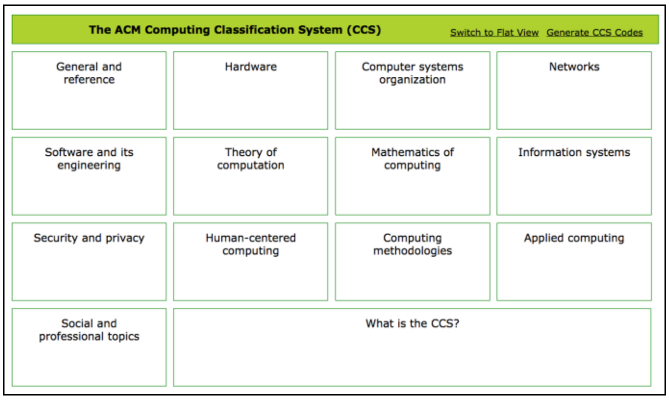

Figure 3: The main categories of the ACM CSS [26]

SKOS is based on XML and was published 2009 by the W3C [28]. It represents a standard to support the use of knowledge organization systems in the field of the semantic web (in this case to describe a taxonomy).

D. Learning Tools Interoperability

LTI specifies a standard for integrating learning applications such as forums, chat rooms, wikis, assignment tools, and video-streaming into platforms like LMS, see [7] and [8]. In an LTI-context, tools are called ***Tool Providers***, and platforms are ***Tool Consumers***.

The recent LTI-version is v2.0, which includes the features defined in versions v1.x, and adds additional functionality; the specification can be found in [7]. The following points are essential for the development of our prototype:

- Launching external resources (since v1.0);
- Returning outcomes to consumer (since v1.1);
- For extensions concerning CBL support v2.0 will be required.

An appropriate way to prepare a learning management system to install connections between courses and resources hosted by LTI-tool-providers is to use (or develop) an according activity-type, which enables the LMS to act as a tool consumer. An instance of this activity-type has to contain authorization parameters as well as essential information like the URI of the resource to connect to - for example an assignment. When an LMS-user enters a course, the connection can be represented by a link to the activity-instance so that for example a request for launching a certain resource is sent via mouse click.

To secure access, LTI uses the standard ***OAuth***; this is a standard for authorization, which has been developed from the ***Internet Engineering Task Force (IETF)*** [9] [10]. The verification of a request roughly works as follows: On the consumer side, a request has been signed with a token, generated from the ***Consumer Key*** and the ***Shared Secret***. The provider uses the ***Shared Secret*** to decrypt the token. In case the result is the consumer key, the sender is identified as the LMS, respectively an activity-instance inside of a course which is hosted by the LMS. This is a strongly simplified description; in fact the procedure is much more complex.

Once the sender is authenticated, further parameters - such as user, context and role - will be identified. Until this stage, the request is only known as generated by an LTI-activity on LMS-side. The provider will handle the decision upon granting access to any demanded resource. If approved, the user will be logged in automatically, meaning that the provider will create a user session. The provider tool then can be launched inside of the requesting course - for example, in an iframe or a separate window.

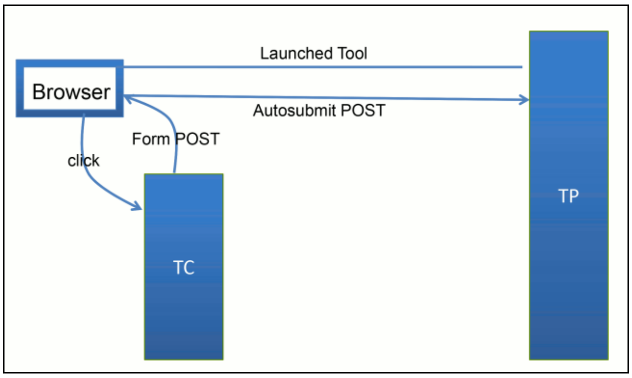

Figure 4: LTI: Launching an external resource [8]

Figure 4 displays the process of launching a tool. The LMS-user starts this process by clicking on any link to an LTI-activity-instance representing a connection to a protected resource on provider-side. In this example, the tool consumer 'TC' prepares the launch parameters, signs them via OAuth and then sends a message back to the browser from where it was originally posted. From there it is automatically - this feature is likely to be developed in JavaScript - forwarded to the provider 'TP'. The provider verifies the consumer via OAuth, and in the case of success, it checks further submitted parameters. If access is approved, the external resource can be launched inside of the requesting LMS-course. For an example including a more detailed view on OAuth see [29].

The tool launch is part of LTI since version 1.0. In v1.1 a procedure has been added, which specifies a way to return outcomes back to the consumer, see Figure 5. Its purpose is to enable learning platforms to receive assessment information like scores and comments from external tools; for example the LMS Moodle stores this information in the students' grade books. The associated notification mechanism is completely asynchronous with the tool launch, i.e., a provider could for example transfer the latest results per cron-job every few minutes.

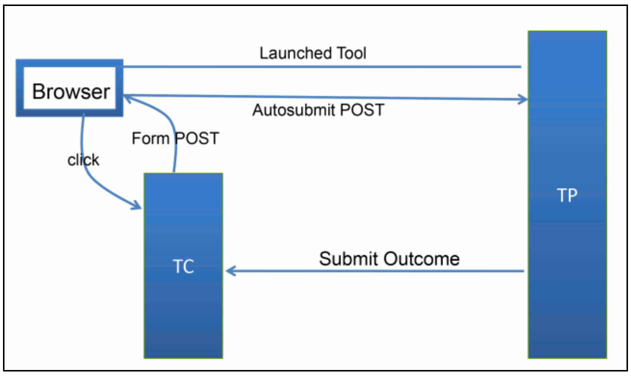

Figure 5: LTI: Submitting outcomes [8]

Returning outcomes back to the consumer has been the first feature in LTI including web services. Version 2.0 introduces additional services [7] [8] offering the following:

- a wider range of information and not just a score can be returned as the so-called outcome;
- providers are enabled to inspect consumer-side resources like courses and course sections;
- providers may check enrolments in consumer-courses;
- providers can be configured to store data on consumer-side.

Before LTI v2.0 returning outcomes has been the only feature which allowed a provider (external tool) to return data to the consumer (e.g. a LMS). LTI v2.0 not only introduced additional web services on consumer-side, it provides a plugin-interface, which offers the possibility to extend LTI-connections by in-house developed web services in a determined way. The option of integrating in-house services could be the key for the information exchange concerning Competence Based Learning between provider and consumer.

From the point of view of security and privacy, some of the new possibilities can be regarded as critical. LTI offers a standardized way to define individual interface contracts between the involved applications. Such a contract, called *ToolProxy*, determines which services shall be used by the participants. This way, critical features may be blocked on each side of the connection by setting the configuration parameters accordingly.

Each involved group, such as software developers, administrators, teachers and students, can benefit from LTI in different ways: A developer of external tools does not need to have a deeper understanding of the providing platform itself, and might handle it as a black box. Furthermore, he or she is free to choose the preferred language and IDE for any development process. Probably the most important advantage is that a single user interface is suitable for each consumer.

The administration of a learning platform, usually a learning management system, profits from LTI as well. It is no longer required to install and test different integrations for each tool-provider. Besides, security and performance of the LMS are not affected, because the connected tools are running in separate environments. Besides, updates of the LMS are less risky as long as the underlying LTI extension is not corrupted by an update. Another helpful feature (depending on the know-how of the involved users) consists in the possibility to authorize teachers to add LTI connections all by themselves.

Last but not least teachers and learners benefit from LTI, because it minimizes the necessary effort to use external applications with learning management systems. Furthermore, the choice of tools is only limited by the institution, encouraging the creation and development of other applicable e-learning tools. This process nourishes an environment for improving the quality of modern education.

E. Personal Competence Manager

The first software project implementing parts of the PCDM (Figure 2 and [16]) has been the ***Personal Competence Manager (PCM)*** [15] [18] [20] [21], an open-source software which is based on ***Liferay*** [33]. The PCM supports individuals, groups and organizations through the lifelong competence development. Apart from the learning process itself, it enables students to use a distinctive collection of functions in the field of network based learning, like the creation of communities and conversation via forums or blogs. The PCM is divided into two parts - a portal environment realized with Liferay and a stand-alone system which can be used without the portal. Table 1 displays selected portlets.

In Figure 6 the persistent entities of the PCM based on the TENCompetence Domain Model (see Figure 2) are visualized. The entities correspond to the elements of the domain model, except the new ***Evidence*** entity to verify a learner's achievements of particular competences. The ***JournalEntry*** corresponds to the process log element of the domain model to track user activities [20].

TABLE I. THE PERSONAL COMPETENCE MANAGER - SELECTED PORTLETS [18]

Portlet	Description
Goal Orientation	Shows the existing competence profiles which a learner can achieve in a learning network. After a learner has defined the preferences, particular competences respectively, the portal can generate recommendations for suitable competence profiles.
Assessment	Supporting the learner to identify the gap between already acquired competences and learning goals.
Activity Navigator	Generates potential learning plans and assists a learner through different learning-activities to achieve the individual learning-goal.
SLeD und Astro Player	Runtime environment for units of learning (like a course or lesson).
Social Help	A portlet to contact an expert (dialog function).
Competence Model Editor	An authoring tool to care for, and create competence model entities.
QTI Editor	Creates quizzes, assignments and tests.
Learning Path Editor	A portlet to create a course of actions. The result is a learning path.

Besides the persistence entities there are data objects, which are not ad hoc persistent, but can turn into persistence entities at runtime, see Figure 7. Core entity is a ***LearningPath*** with at least one ***CompetenceLevel (CL)***, which students can

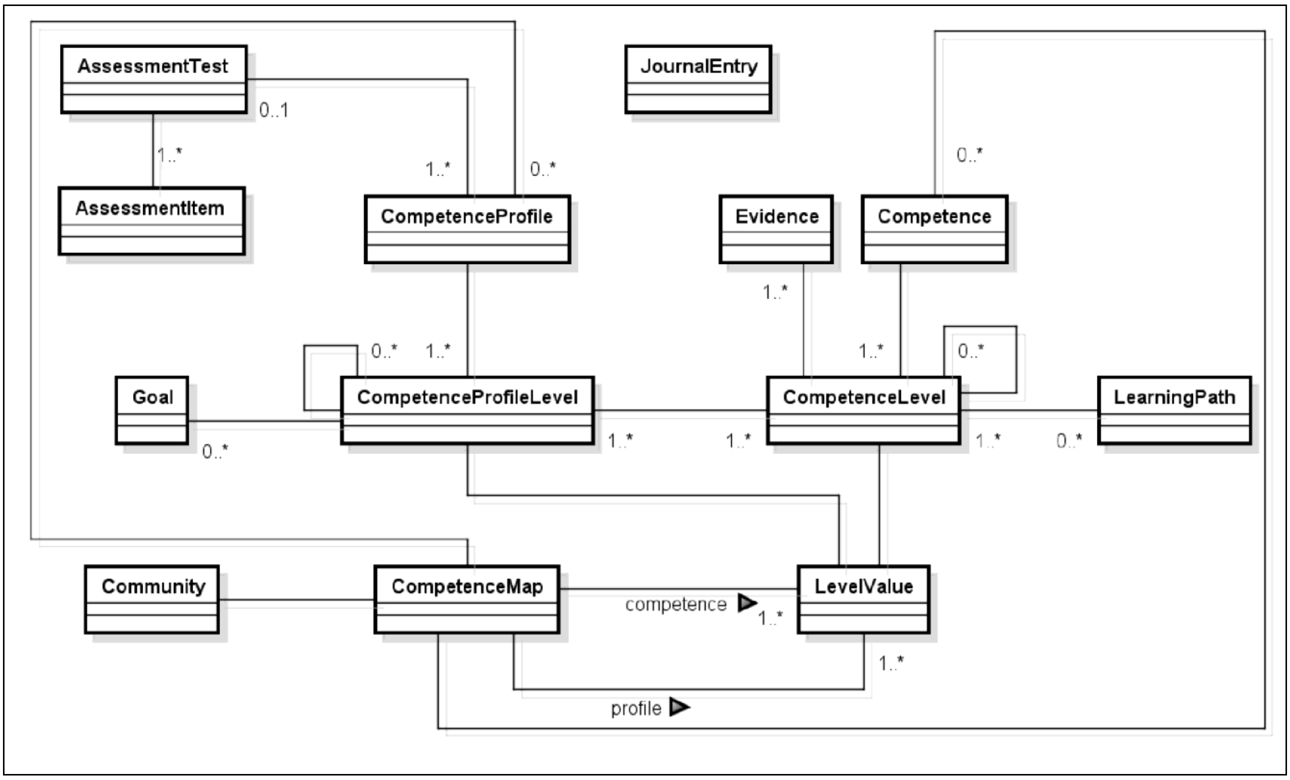

Figure 6: Persistence entities of the PCM [20]

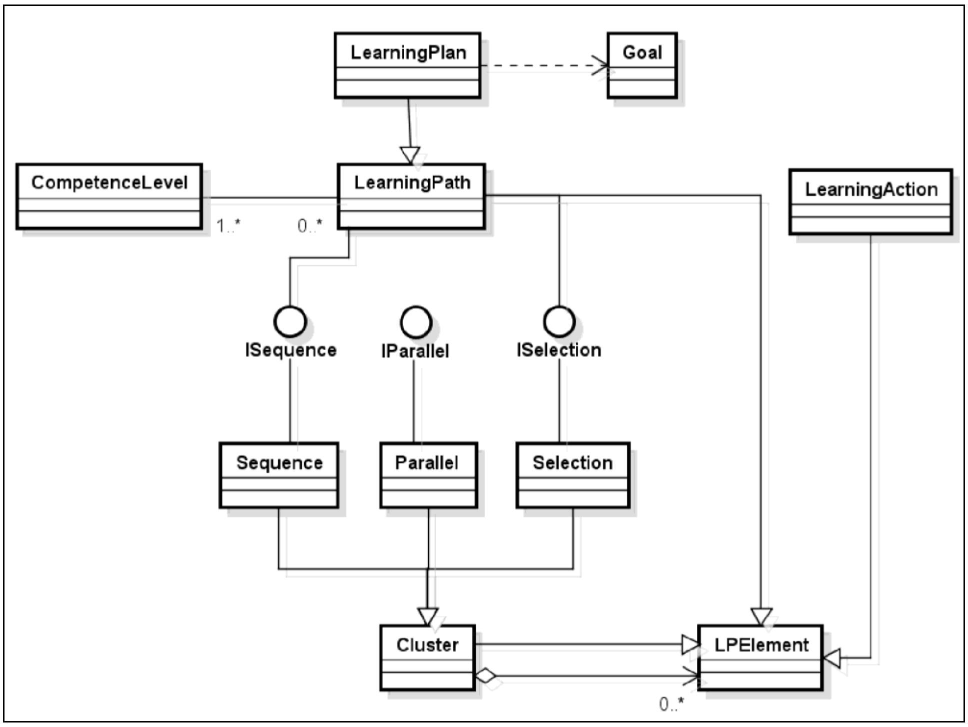

Figure 7: Learningpath entities [20]

achieve by mastering the path. LearningPaths can collect three types of clusters:

- sequence with a fixed order of learning activities;
- parallel, where defined learning activities can be executed simultaneously;
- selection, where a learner must execute a defined number of activities but in random order.

F. *Ecosystem Portal*

Another software solution claiming to support Competence Based Learning is the ***Educational Portal*** toolkit. It has been developed by the software company ***GLOBIT*** [23] and is currently extended into an ***Ecosystem Portal (EP)*** toolkit by the research institute ***Forschungsinstitut für Telekommunikation und Kooperation (FTK)*** [34] in the European coordination and support action ***RAGE*** [35]. It is based on the CMS ***Typo3*** [36] and will offer extensions for the use of competences and learning goals in the foreseeable future. Furthermore, a wide variety of useful tools is already provided by now (see Figure 9), including a web-based, user-friendly course authoring tool called EP-CAT, which is an appropriate starting point for our authoring tool and therefore prevents us from re-inventing the wheel.

One of the most attractive qualities of the EP-CAT is its intuitive and web-based user interface, which immediately enables users to start their creative approaches towards innovative developments. This is a solid basis to engineer further tools for meeting one of the key-goals of the new authoring tool project: user friendliness. In [29] the need for tools like the EP-CAT is discussed from the viewpoint of educational institutions.

Another important feature coming with the EP-CAT is that there are ready-made course templates, which can be used and extended instead of starting a course design from scratch. Users with little knowledge about the bits and pieces of computer systems or virtual learning platforms might immediately be enabled to design their online-courses without further learning overhead involved. Instead, they can fully concentrate on contents or didactical strategies without getting lost by having to read bulky and difficult to follow user manuals.

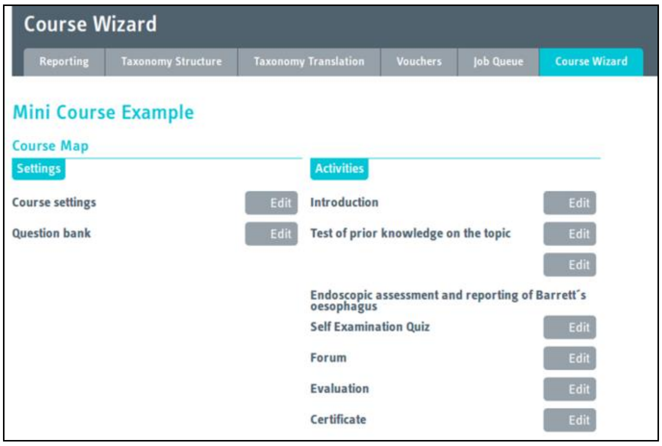

Figure 8: EP-CAT - Course Wizard, Course Map

Figure 8 displays an example of such an intuitive web-based user interface for creating courses with competence information. Another important advantage of this solution is

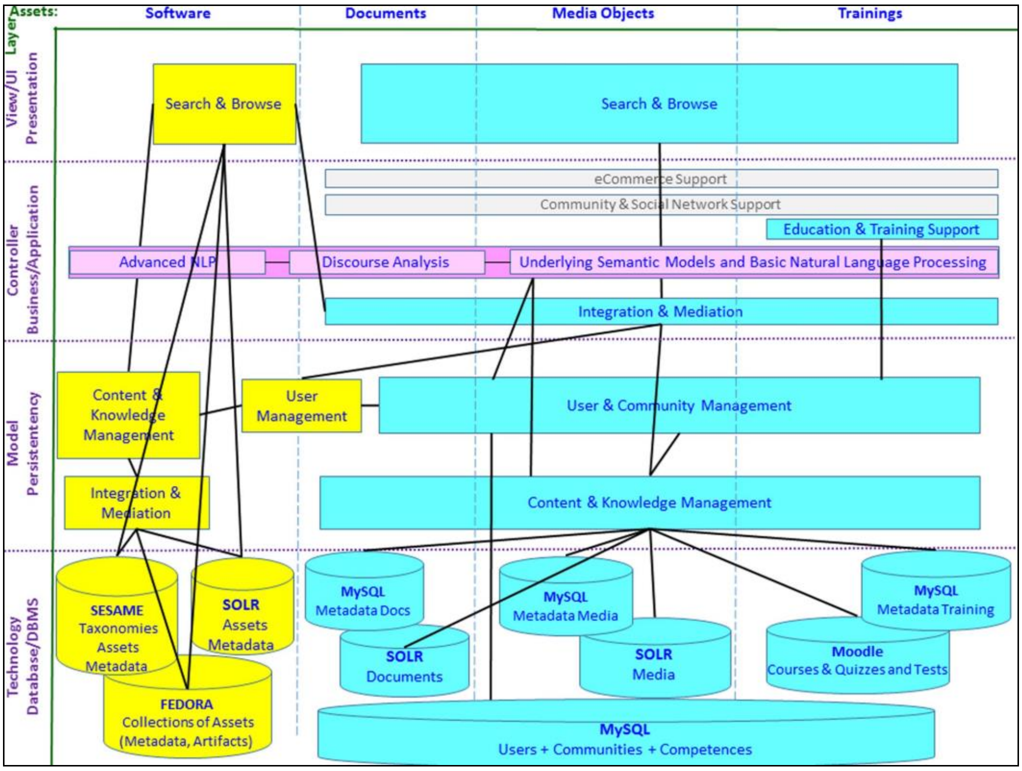

Figure 9: The Ecosystem Portal (EP) - an architectural overview

that such creations can be transferred to the LMS Moodle with a single mouse-click.

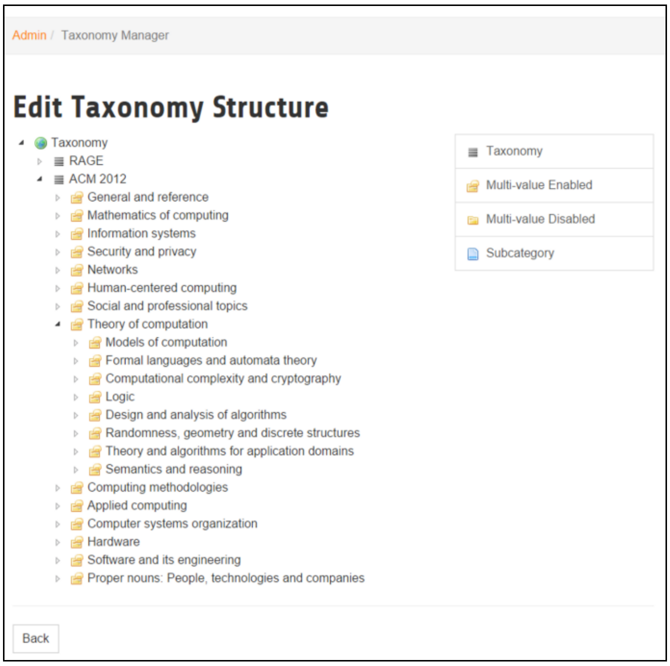

Figure 10: Support for the ACM-CCS-taxonomy in the EP

The EP already supports the classification of knowledge resources. For this purpose, so-called ***Categories*** are used, which can be created manually with the ***Taxonomy Manager*** ***(TM)*** or via XML-import from standardized taxonomies; Figure 10 shows the structure of the 2012 *ACCS*. It has been applied in the EP within the RAGE [35] project. Extensions for SKOS import and version management are scheduled for the future.

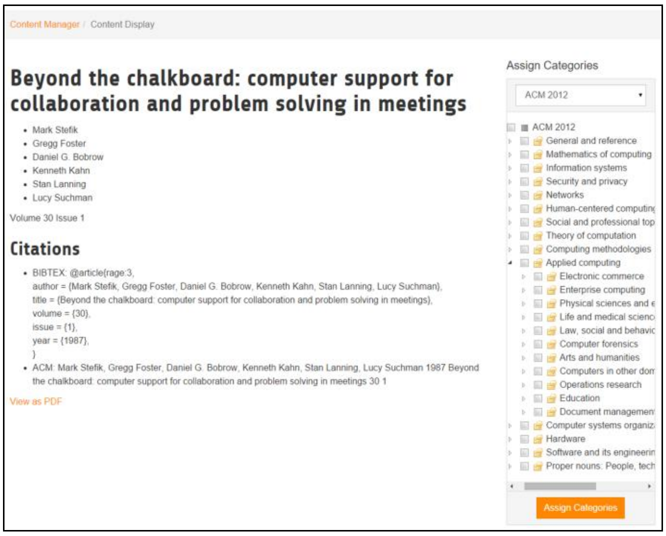

Figure 11: Assigning skills to a knowledge resource in the EP

Figure 11 displays the user interface for assigning taxonomy categories to a content object - in this case the taxonomy itself is a knowledge resource as well as the semantically tagged content object. The functionality is realized by the Typo3 plugin's ***Categorization Editor (CE)***, which is part of the Typo3-extension ***globit_taxonomy***. The user just has to select some categories corresponding to the content object; by clicking the assign button the relations will be saved. Afterwards, the page will be reloaded and the related categorizations will be listed at the bottom of the page and preselected in the tree to the right.

From a technical point of view, content objects as knowledge resources and their connections to knowledge resources represented by taxonomy structures are managed by the Typo3 extensions ***globit_sto*** and ***globit_taxonomy***. The latter contains a so-called ***Taxonomy Editor***, allowing users with administrator privileges to create taxonomy trees (see Figure 10 for an example). A taxonomy tree represents so-called ***Knowledge Concept Nodes*** for classifying a library of skills into categories and subcategories. The extension also offers a multi-language mode, so that translations for category names can be provided for each supported language. Figure 12 displays the involved database tables, which are related to the extension globit_taxonomy, storing the information about taxonomy structures and categorizations of content objects.

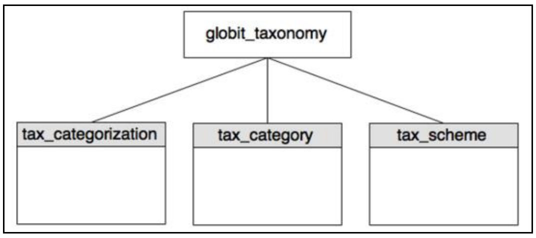

Figure 12: Database tables managed by the Typo3 extension *globit_taxonomy*.

The EP does not yet support competences and learning goals in a PCDM-compliant way. Using standardized taxonomies is an important step into the right direction, but there are still several issues to solve.

G. *Moodle's LTI Consumer Plugin*

The idea of integrating external e-learning tools into Moodle is already supported; the Moodle community saw the potential of this technology and developed two plugins, see [20] and [37]. The plugin ***External Tool***, also referred to as LTI Consumer Plugin, enables Moodle users having admin- or teacher privileges to integrate protected resources from external applications into Moodle courses via LTI. The user does not need to have any deeper knowledge about LTI, but a basic understanding is still necessary. In the context of our project, Moodle will act as a tool consumer, and so the LTI Consumer Plugin will be the starting point on Moodle side. In recent Moodle releases from version 2.8 onwards LTI v2.0 is supported; earlier versions support LTI v1.1.

Creating such a connection can be quite simple, as long as the external tool supports LTI; at [38], a list of certified tools is available. Implementing LTI-connections between Moodle and legacy software like WA implies making these tools LTI compatible. Several universities, for example the University of Duisburg-Essen, adapted their internal developed assignment software for this purpose. However, their tool ***Jack*** [39] is catered to the needs of the University Duisburg-Essen and their way to implement LTI support does not suit to our requirements. Moodle itself can also be used as a tool provider: this requires the installation of the plugin described in [37].

To gain a first experience of working with LTI, we have built up a test environment containing two separate Moodle instances: Moodle A acts as a tool consumer, Moodle B as a provider. Figure 13 displays an example, where an assignment in Moodle B is used by a course in Moodle A. It probably would make sense to suppress the header and the blocks of Moodle B. Anyhow, for demonstration purposes both Moodle instances are displayed. When launching the assignment, the active user in Moodle A is automatically logged into Moodle B. The login procedure itself is handled completely by the provider.

Figure 13: Two Moodles, connected via LTI.

The LTI Consumer Plugin offers a service for receiving information such as scores. Moodle's provider plugin periodically requests this service per cron-job, which identifies new results and transfers them back to the consumer. Finally the information does not only exist on the provider-side but also in the Moodle course's grade book.

Since Moodle version v2.8 [1] the consumer plugin supports LTI v2.0, and an interface for integrating further web services is available. This offers a way to exchange competence information between Moodle and tool providers via in-house developed services.

H. Remaining Challenges

It can be said that an innovative software solution which is going beyond the state of the art has to be developed, and so the following requirements have to be considered:

1. Integration of external tools into LMSs via LTI, including meta-information for CBL support.
2. Development of an extended CAT offering a user-friendly way to create and modify online courses, which will later be proceeded in LMSs.
3. The CAT has to run in an environment, which equips learning content with competences and competence profiles, therefore dealing with CBL information based on the PCDM is obligatory.
4. Course data together with integrated CBL information have to be transferred from the CAT to the LMS, so a mechanism for exporting/importing data has to be provided.
5. The exchange of CBL information between multiple systems prerequisites a common pool of data containing all available competences, profiles, and levels. Ideally this data pool should be based on a widespread, standardized set of taxonomies.

IV. METHODOLOGY AND CONCEPTUAL SYSTEM DESIGN

To determine a schedule for the development of a framing and interconnecting learning content authoring software, fundamental considerations concerning the architecture have been made. CBL compliance is a core requirement, so an appropriate way to handle and exchange competence information has to be found. This affects our CAT as well as the LMS and additional learning tools embedded via LTI and leads to the triangle displayed in Fig 14.

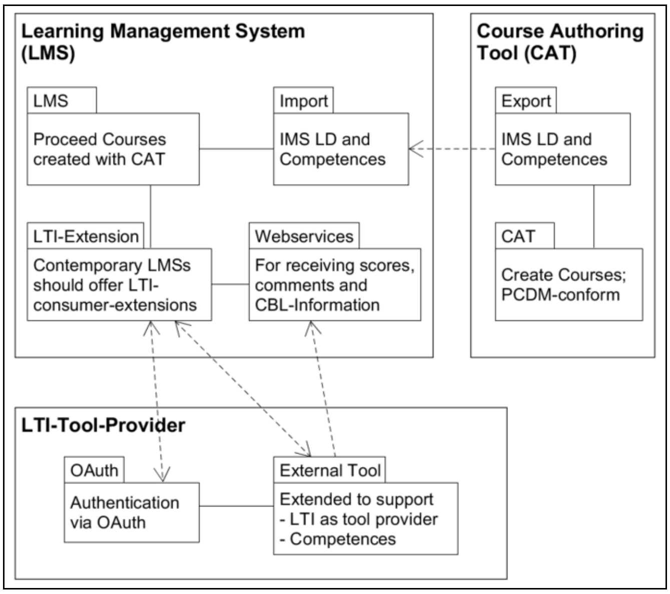

Figure 14: General architecture

The workflow for developing a course containing activities, knowledge resources and competence information starts with its creation in a CAT. From there it is transferred to the target-LMS by using an appropriate import/export-mechanism. If the resulting course contains external resources hosted by an LTI tool-provider, the LMS has to act as an LTI tool-consumer, which implies an appropriate extension has to be installed. Aside from authentication via OAuth and features like returning scores, information flows from the LMS to the external tool.

Advanced functionality, such as returning elaborate assessment information to a student's exercise, requires support of LTI-Version 2.0 on the side of the LMS. Additional web services have to be implemented, which swiftly can be integrated via LTI-2.0's plugin interface. In the case of CBL support on provider-side, the same mechanism can be used to exchange competence information with the connected LTI resource. Indeed this is eligible, but not essential; otherwise it would limit the choice of available tools in a significant way.

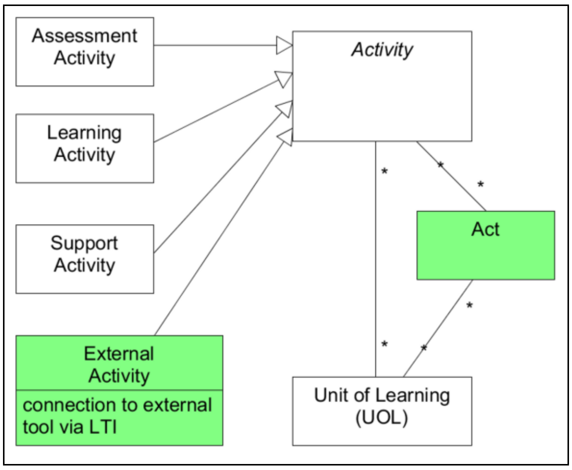

Figure 15: UML Class Diagram [25] - PCDM-extensions *External Activity* and *Act*

The domain class model used for the approach presented in this paper is based on the PCDM. Modification of the PCDM is necessary, because it does not consider distributed solutions like LTI yet, and its ***import/export-interface*** for ***units of learning*** is limited to IMS LD - so it offers no support for the exchange of CBL information with other systems, see Figure 2. Unlike IMS LD, it does not contain a class ***Act*** or ***Activity-Structure*** to divide a UOL into different ***sections***, which can lead to conflicts when exchanging data with an LMS.

In Figure 15 two additional classes are introduced to the PCDM - ***Act*** and ***External Activity***. As Moodle and most other LMSs divide courses into smaller units - in Moodle called *sections* - a corresponding class has been added and named *Act* in analogy to IMS LD. The class ***External Activity*** enables the PCDM to integrate resources from external learning software via LTI connections. It inherits the properties of the abstract class ***Activity*** and adds some information, which define a connection between a UOL and an LTI resource.

To provide PCDM's ***IMS-LD import/export-interface*** with support for the exchange of CBL metadata, an appropriate extension has to be introduced, see Figure 16. In addition or as an alternative to the xml-based exchange format, ***Moodle's Webservice-API*** could be used.

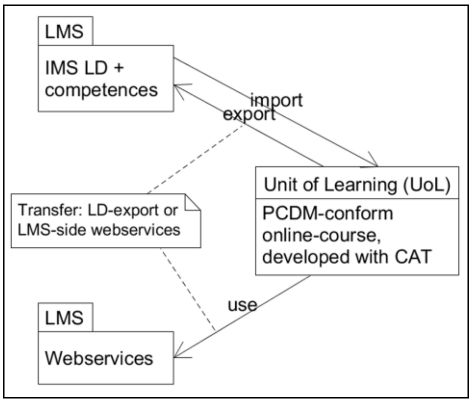

Figure 16: UML Class Diagram [25] - PCDM-extension for LD-Export and web services

The fundament of a BP- and PCDM-conform structure for classification and categorization of competences and learning goals consists of standardized taxonomies, which are both machine-readable and accessible for humans. Consequently, the ACM CS taxonomy will be imported, because it describes the different categories within the field of computing and is available in the XML-based SKOS format.

Categories and skills originated from standardized taxonomies cannot be regarded as synonyms for competences and -profiles, but the gap can be bridged by defining relations between PCDM- and taxonomy-elements. A general definition for these relations depends on different factors, including the taxonomy's hierarchical order, which has to be mapped to the PCDM-structure consisting of competences and -profiles.

V. Initial Implementation Approach & Prototype

As a proof of concept, the learning content authoring software described above is designed and implemented with regard to the use case scenario "*FernUni*". The tool landscape therefore consists of the LMS Moodle and FernUni's legacy assignment software WA as the external tool to be embedded into Moodle via LTI. The CAT will have to exchange course- and competence-data with Moodle. The Ecosystem Portal's course authoring tool (EP-CAT) has been chosen as the starting point for designing the aforesaid CAT. Assuming the PCM-extensions displayed in Figures 15 and 16 and availability of suitable web services on the side of Moodle, the platform specific architecture displayed in Figure 17 is obtained.

A. Embedding WA into Moodle

This section presents a case study for the integration of legacy learning tools into Moodle - the connection between Moodle and WA. In LTI jargon Moodle is the tool consumer, because it accesses resources from the external tool. WA provides these resources; so it is the tool provider.

The Moodle side of this connection will be less problematic, since Moodle already offers appropriate support with its LTI Consumer Plugin. In addition to LTI's core functionality, it offers the possibility to integrate additional web services in an LTI compliant way by using the intended

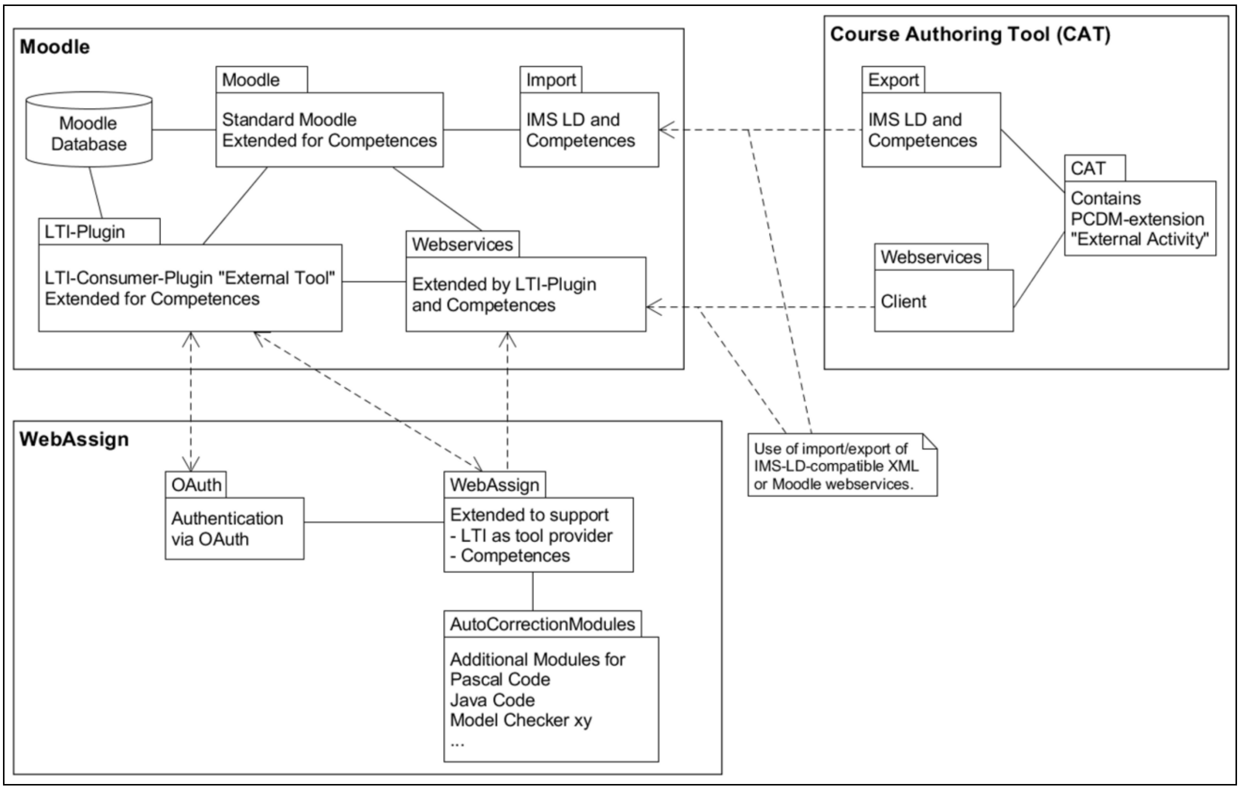

Figure 17: Use Case Scenario *FernUni* - Software Integration Architecture

interface. Therefore, implementing and introducing suitable web services should be sufficient for our purposes; modification of the plugin itself will not be necessary.

From the provider side a considerable effort has to be taken into concern, because like most legacy software, WebAssign does not support LTI yet. First of all, a requirements specification including decisions about the capability range of the Moodle-WA-integration is needed [29]. Apart from this, authentication via OAuth and transferring outcomes from WA to Moodle are obligatory.

1) Requirements and Decisions

A typical course at FernUni is divided into four or seven units - depending on workload and credit points according to the ECTS [3]. Each unit of a FernUni course contains an optional exercise booklet. These booklets serve as containers for assignments. Since this structure has been part of the requirements for the development of WA decades ago, it is perfectly integrated into WA. A disadvantage of this structure is that WA is limited in its way of organizing assignments outside of the scheduled units-plan, which is a barrier for asynchronous studies. Concerning the LTI-support, it has to be decided if single assignments, whole booklets, or both possibilities should be integrated.

The core feature of the connection is to launch a WA resource from within a Moodle course without disturbing the user’s workflow. The research is in the state of investigating the possibilities and needs - mainly by focusing on didactical aspects, focusing on the fact that new authoring tools are developed to support teaching and learning processes.

Up to now it is unclear, which types of resources and which workflows shall be integrated in Moodle. A prototype solution the following points can be considered:

- Students working on their assignments;
- Teachers creating and editing assignments;
- Teachers using the correction workflow.

Since students should not be aware of WA as an underlying platform, the first listed workflow is essential here.

Several assignment types require manual marking by a grader, who in some cases also writes reports and statistics. In addition, quite a few tutors, mentors and teaching fellows use a point-system along with quizzes and assignments - either to show the students their learning performance, or to create a filter by having a minimum of assignments-points set to allow only students who meet these minimum requirements to participate in a final exam. Assignment booklets are usually handled as pdf files. WA offers a capable workflow to manage the marking process - including features like the automatic distribution of assignments between teachers and graders. The distribution modes can be individually configured; this would be an advantageous feature in Moodle, making the usability of external tools even more desirable.

WA also offers an interface enabling teachers to employ additional tools for checking students’ answers to assignments and problem sets, as they - for example - occur in the field of computer science. In WA, teachers may integrate their own analyzers for verifying and testing program code, written in Pascal, Java or C++. These kinds of additional tools will probably not affect the development of connections between Moodle and WA directly, but they should be kept in mind for further improvements.

2) Considerations and Technical Aspects

Resource owners in WA need an interface to authorize and withdraw LTI connections.

LTI requires OAuth support, which is currently not available in WA, so an appropriate extension has to be discovered and installed. Successfully OAuth-verified requests have to pass some further checks:

- Sender: The sender needs to be identified, and data must be compared to the list of verified WA users. Furthermore, it has to be checked, if the sender is authorized to access the resource.
- Requested resource: An approval of the request is needed, because several resources only have a granted access during limited time periods.

If the access is permitted, the sender has to be logged in automatically, which includes creating and initializing a secure session. Next step is to generate a browser-readable presentation of the requested resource.

Last but not least a workflow for returning outcomes to Moodle has to be developed. As this process will be asynchronous, a possible solution might be to execute a cron-job on a regularly basis.

B. Categorization of learning content

The EP, in particular its EP-CAT and its taxonomy management, is one of the fundaments for our learning content authoring strategy. A solution to enrich activities and resources with PCDM compliant competences and learning goals could be to turn EP’s taxonomy extension into, respectively expand it to become, a competence management tool. The workflow of assigning competences to learning content could be implemented in analogy to the already implemented procedure for assigning categories of the ACM CCS taxonomy to knowledge resources, see Figure 11.

The next step is to make some further decisions concerning the interaction between competences and taxonomies in the EP, which eventually could cause the need of further PCDM-extensions.

C. Moodle Plugin for CBL

The platform-specific architecture displayed in Figure 17 requires Moodle to receive learning content with competence information from the CAT, for this reason suitable import/export-functionality has to be provided, Figure 16 shows further details. From a developer’s point of view, there are three possibilities:

- implementing an xml-parser for LD- and CBL information exported by the CAT;

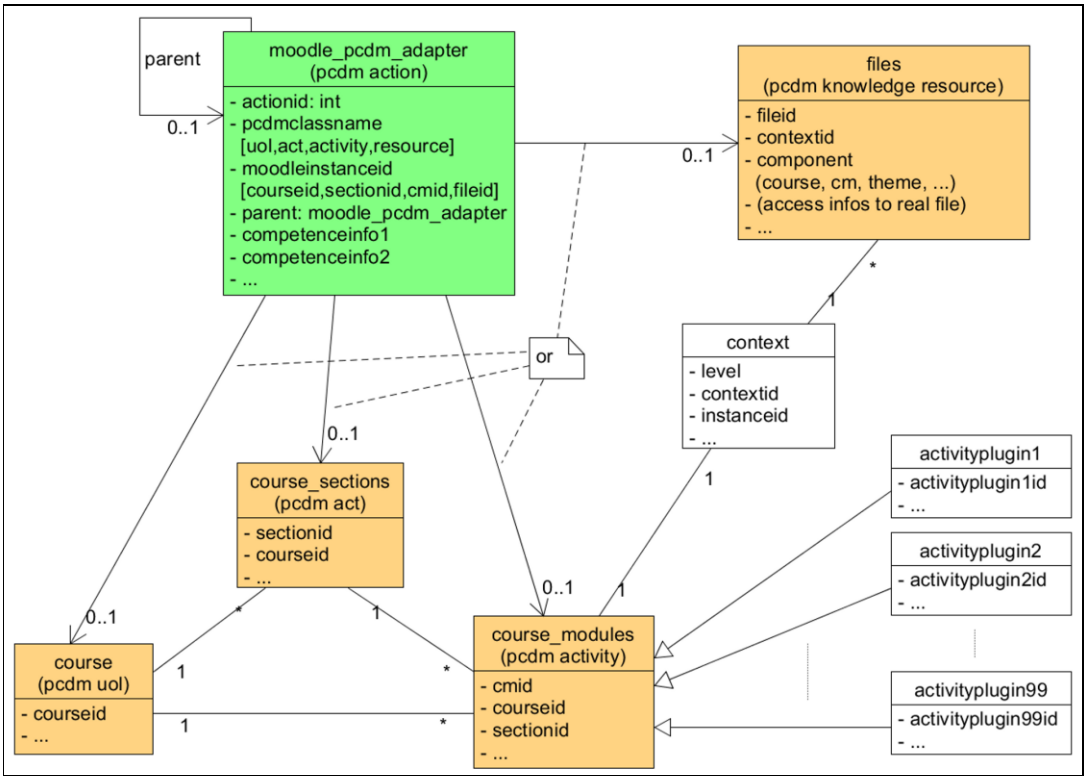

Figure 18: UML Class Diagram [25] - Mapping from PCDM to Moodle

- using available Moodle web services and writing additional ones for transferring CBL information;
- a combination of both.

A first step to tackle this task is to identify distinct relations between the CAT's PCDM-based class model and Moodle's database tables. Moodle does not work object oriented in the case of courses and activities, so on Moodle side there is no domain class model, which could be used. Based on these relations CAT-content can be transferred to Moodle; below a Moodle extension providing such a mapping is presented.

The diagram in Figure 18 displays the involved database tables in the form of domain classes with orange background. A comparison between these tables and the extended PCDM (Figure 2, Figure 8) indicates, that every PCDM-element involved in the exchange of CBL information has a counterpart in Moodle:

- unit of learning → course
- act → course section
- activity → course_module
- knowledge resource → files

The database tables ***activityplugin1..99*** are standing for Moodle-activity-plugins like forum, quiz, wiki and many more.

Developing a plugin appears to be the method of choice for integrating CBL extensions into Moodle, because its plugin-interface enables programmers to add new functionality without touching the core code. In fact, most Moodle features, for example all activities, repositories, and filters, are plugins. Encapsulating the core code and adding extensions over a specified interface reduces the risk for side effects and improves the flexibility and maintainability of a Moodle installation, for example in case of upgrades.

Implementation of a mapping from a CAT conform learning content with CBL information to the Moodle database requires new, plugin-specific tables on the side of Moodle, which extend the core tables with competence specific structures. The table ***moodle_pcdm_adapter*** in Figure 18 acts as the counterpart to the abstract class *action* in the PCDM (see Figure 2), serving as a bridge between learning content and competence information.

Transferring a PCDM-resource to Moodle could work the following way: Assumed, the activity ***quiz-q321*** has been created with the CAT and is part of act ***a2*** in the UOL ***course-c789***. To import it into Moodle, first a ***moodle_pcdm_adapter*** entry ***ad-q321*** is created in the database. If an adapter ***ad-a2*** for a2 already exists, it is connected to ad-q321 via the parent relation; otherwise ad-a2 first has to be created. Then the field pcdmclassname is set to ***activity*** and moodleinstanceid to ***cmid***. As PCDM-activities are mapped to corresponding plugins in Moodle, a ***course_modules*** entry ***cm-q321*** has to be added for our quiz. If a ***course_section*** entry for a2 and a ***course*** entry for course-c789 already exist in the Moodle database, they are connected to cm-q321 as shown in Fig. 18; otherwise they first have to be created. The table course_modules only contains the general properties of an activity, the specific information is stored in the ***activityplugin-tables***; in the case of quiz-q321 an entry has to be created in the table ***quiz***. Fig. 18 does not include the mapping of CBL information; this is just indicated by the competenceinfo entries in the moodle_pcdm_adapter table.

The mapping from CBL elements like competences and learning goals to Moodle is depending on decisions, which have to be made in the context of the categorization of learning content, see section B. Moodle's ***outcomes*-**feature [40] seems to be an appropriate starting point for extending courses, activities and resources with PCDM compliant competence information. A promising alternative could be the Moodle project ***Framework for Competency-Based Education (CBE)***, which is intended to introduce support for competences into future Moodle versions. At the moment it is still at an early stage of development and a prototype or source code is not yet available, but the concept presented in [41] seems to offer some interesting points of contact for us.

D. Course Authoring in CAT and Moodle

Relying on a particular learning content authoring tool with an easy and intuitive user interface implies that Moodle courses will be created from outside of Moodle and have to be transferred to Moodle in one way or the other. As previously described, this requires a Moodle extension - ideally implemented as a plugin. For loosening the dependency between CAT and Moodle to a certain degree, this plugin may be equipped with a simple user interface offering some basic features for creating and editing courses on the side of Moodle. Encapsulation of the plugin's application logic in the meaning of the ***Model View Controller (MVC)*** [44] software design pattern opens the possibility to create courses with CBL support from different user interfaces, including the CAT and Moodle itself. As an example for this approach, we have developed a slim plugin, which enables Moodle to clone an eligible course with one mouse click. Cloning can be triggered from a user interface within Moodle or from a web service, which can be called by external authoring software like the CAT.

VI. SUMMARY AND FUTURE WORK

Several key issues of our research goals, requirements, state of the art and approaches have been presented. Along the state of the art in this paper, we have identified important milestones for project development and defined the following subprojects:

- integration of external e-learning tools into Moodle via LTI;
- development of a user-friendly CAT based on GLOBIT's EP-CAT;
- extending the CAT for support of CBL;
- development of a Moodle plugin for CBL support, which offers web services for data exchange with the modified CAT;
- development of a competence management tool based on standardized taxonomies.

A concept for achieving these milestones has been introduced by means of the development of a competence-based course-authoring model and a concept for integrating external e-learning tools into Moodle via LTI. From a technical point of view, we have identified Moodle, LTI, the PCDM, the EP and ACCS as suitable fundaments. As our approaches go beyond these technologies, appropriate extensions are inevitable; the resulting architecture incorporates these extensions.

One key issue of this paper has been the concept for integrating external e-learning tools into Moodle via LTI. To gain the necessary technical expertise, experience and data for this research project, an LTI connection prototype will be designed and implemented from scratch, implying the extension of the tool provider for LTI support. Working with LTI ready tools is not sufficient in this scenario, because later the connection must be extended for the use of competences, making a deeper knowledge inevitable. The prototype will connect Moodle and WA; latter was the tool of choice, because its Moodle integration is demanded at FernUni.

Focusing on software architecture, we analyzed the PCDM and proposed appropriate extensions concerning the support of external tools and data exchange with Moodle. The resulting class model is one of the key stones of our architecture.

Furthermore, a concept, which integrates standardized taxonomies into the CBL process by turning the Ecosystem Portal's taxonomy manager into a competence management tool is in development. A basic XML-import-functionality for taxonomies is already available and will be extended for SKOS support soon.

Finally, we outlined a Moodle plugin, enabling Moodle to deal with competences and exchange CBL metadata with particular authoring tools like a modified CAT. The design of this particular Moodle plugin is not yet complete because it depends on the solution for the management of competences and taxonomies. This is under development at the time being. Encapsulation of our plugin's application logic in terms of the MVC pattern offers the possibility to create and edit courses from within Moodle as well as from particular, more user-friendly authoring tools like the CAT.

In the case of FernUni's learning environment, Moodle has been the LMS of choice and therefore played a significant role in this paper. But every CBL scenario comes with its own requirements concerning the selection of the most suitable LMS, so for achieving as much flexibility as possible, further learning platforms have to be investigated with regard to CBL.

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